BEAM AND COLUMN DATA

COMPLIMENTS OF

NORTHWESTERN EXPANDED METAL CO.

930-950 OLD COLONY BUILDING

CHICAGO

TELEPHONE--HARRISON 799

Factory CHICAGO, ILL.

Factory CANTON, OHIO

MANUFACTURERS OF

TRADE MARK

FOOL PROOF REINFORCING

NORTHWESTERN EXP. MET. CO. CHICAGO

AND

"KNO-BURN" EXPANDED METAL PLASTERING LATH

WHEN EXPANDED METAL REINFORCEMENT IS USED IN SLABS ***ALL THE AREA OF THE STEEL*** IN CROSS SECTION IS ***AVAILABLE FOR REINFORCEMENT.*** NO ADDITIONAL STEEL IS REQUIRED FOR BINDING OR CROSS BEARING PURPOSES

IDEAL REINFORCEMENT FOR CONCENTRATED LOADS AND TO CARE FOR INDETERMINATE STRESSES

CANNOT SLIP. NO LOOSE JOINTS. NO WEAVING. NO WELDING. SHEARED FROM SOLID PLATES.

The Northwestern Expanded Metal Co.

Designing Booklets

Sent "Free on Request"

No. 1. The Use of Expanded Metal.—A reprint of an article in the October, 1908 issue of Concrete, by Ernest McCullough. (Out of print.)

No. 2. Concrete and Steel.—Contains valuable hints to architects on the preparation of specifications for reinforced concrete construction. (Out of print.)

(Subject-matter in booklets out of print is scattered through other booklets in the series.)

No. 3. Kno-Burn Metal Plastering Lath.—An up-to-date manual for plasterers containing recipes for mortar mixtures and coloring of mortar. Also describes Kno-Burn Metal Plastering Lath with instructions for use of same and specifications.

No. 4. Roof and Floor Slabs.—Contains 13 tables giving strength and carrying capacity of slabs varying in thickness from 1¼ inches to 12 inches and with spans from 3 to 20 feet, reinforced with expanded metal. Contains also other valuable tables for designers.

No. 5. Beams and Columns. — Supplementary to No. 4 and comprising with it the most complete manual on reinforced concrete design that has been issued by any manufacturer of reinforcement.

IMPORTANT.

MARCH 31ST, 1909.

We have this date discarded the old method of designating expanded metal by mesh, gauge and width of strand. It lacked flexibility and being confusing led to many mistakes.

Hereafter, prominence will be given to areas and weights thus making expanded metal directly comparable with other forms of reinforcing material.

The change is made for the convenience of customers and we hope that the use of words such as "regular" and "standard" will be discontinued.

Orders however will be promptly filled no matter how the material is described, provided the customer makes his meaning clear.

HOW TO ORDER EXPANDED METAL.

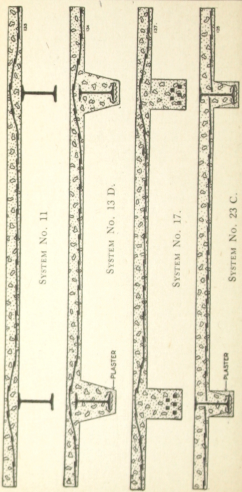
A CAREFUL READING OF THESE INSTRUCTIONS MAY SAVE TIME AND MONEY.

There are no fixed, universal standards for Expanded Metal as for rods and bars.

For the convenience of those wanting to specify our material we have numbers. As other companies have numbers do not forget to give name of company with the number or we will assume our number is wanted.

Customers desiring to procure expanded metal similar to some they have, should order by giving size of mesh and weight per square foot of the material they want duplicated.

Weigh a sheet and give us the total weight and the exact area so it can be figured out in our office. It is best in all cases to send a sample of the material.



SYSTEM No. 11

SYSTEM No. 13 D.

SYSTEM No. 17.

SYSTEM No. 23 C.

trated on page 10, System 37. As steel is cheaper than concrete this last method of reinforcement often pays. It saves the slight trouble of raising the metal at supports. When used in storage warehouse the lower reinforcement often goes straight through and the top reinforcement is additional. This takes care of excessive shear as well as of reverse bending moments.

While the exact amount of reinforcement over supports may be figured and used for slabs and they may be figured as continuous or partially continuous it is not good practice to figure beams and girders except as freely supported with $M=\frac{wl^2}{8}$. Negative bending moments, however, exist at the supports so that steel should be supplied at the tops of beams and girders over supports to take care of $M=\frac{wl^2}{12}$.

The deflection of reinforced concrete beams is only about one-third the deflection of steel I beams of equal strength. A floor slab over a number of reinforced concrete beams can be figured as continuous. It can be figured as continuous if placed over a number of I beams encased in concrete poured when the floor slab is poured. If the I beams however are not encased in concrete then the slab should be figured as only partially continuous because of the greater deflection of the steel beams.

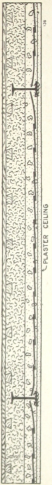
DESIGNING LOADS.

See page 16, Roof and Floor Slab booklet for weights of roof and floor materials.

See page 17, Roof and Floor Slab booklet for live loads generally allowed in Building Ordinances.

The dead load of a structure is the weight of the girders, beams, slabs and roof or floor covering. The live load is a load not constantly applied, although it may be stationary for long periods of time. Superimposed safe load, is a better term than live load and means a load in addition to the dead load. Moments are calculated from total load which is the sum of the dead load and the superimposed safe load.

The factor of safety does not apply to the live load but to the amount of stress in the materials.



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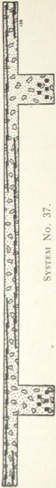

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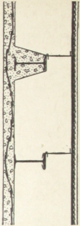
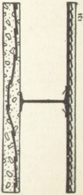


METHOD H.



METHOD G.

A floor designed to carry four times the live load has not a factor of safety of four. If it can carry four times the total load it then has such a factor.

Some designers take half the dead load and once the live load and use a fiber stress in the materials. Actually however the fiber stress under the live load is greater than the specifications call for so the practice is neither honest nor sensible. Too large a proportion of the strength of the materials is exerted in carrying the dead load. This also increases the cost of columns and footings. The owners of reinforced concrete buildings do not understand these things fully enough or there would be less call for long span construction. A number of instances have been reported where the absence of girders and beams produced buildings in which resonance is a decided nuisance and false beams and girders have been put in hallways to break up echoes. This is when the floors are solid. When a ceiling is suspended beneath the floor, to hide the beams so many people object to, there is no resonance.

The best way to design floor and roof systems is to use short spans, thus increasing the strength and stiffness of the structure, reducing weight, which goes to the foundations and makes necessary heavier columns and beams, and lessening cost. If the intermediate beams are considered objectionable suspended ceilings can be used to conceal them. Therefore, assume as a total load one and one-half times the live load and equate for span.

Let W = total load on span.

l = span.

M = bending or resisting moment $= Rbd^2$.

then $l = \sqrt{\frac{8M}{W}}$ for freely supported spans.

$l = \sqrt{\frac{10M}{W}}$ for partially continuous spans.

$l = \sqrt{\frac{12M}{W}}$ for continuous spans.

By using actual loads and taking fiber stresses in the materials the factor of safety desired is obtained. Reinforced concrete formulas wherein fiber stresses are used in connection with safe loads are known as Straight Line Formulas. In this

series of booklets only such formulas are used and the factor of safety is 4. Formulas using the ultimate strength of the materials and breaking loads, are known as parabolic formulas, Straight line formulas give sizes possessing greater rigidity than parabolic formulas and as a rule are the only formulas permitted to be used in cities possessing building regulations governing reinforced concrete.

The span length used should be the clear span plus depth of slab, beam or girder except when this would exceed the distance center to center of supports in which case the latter is the span length. Brackets should not be used to reduce the span length used.

Full dead and live load should be used for slabs and beams. For girders the assumed live load can be reduced 15 per cent. except in buildings used for storage purposes.

In designing columns the full dead load for each floor is carried to the column. As it seldom happens that all floors are loaded at one time to the full amount assumed, the live load is reduced 5% for the first floor below the roof when assuming loads to go to columns; 10% for the second floor below the roof; 15% for the third, etc., until a floor is reached where the reduction amounts to 50% of the live load, after which 50% of the live load is used for the remaining floors.

For slabs supported on the four sides $M=\frac{wl^2}{20}$ when the panel is exactly square. There will be an equal amount of reinforcement in two directions crossing at right angles. This reinforcement will of course be in two layers and the slab thickness found by calculation must be increased by the thickness of the extra layer of steel.

When the length of the panel is greater than the width and is equal to, or less than, 1.5 times the width, the reinforcement must run in both directions, the proportions of load going to the supports on the side being found by the following formula:

Let r = proportion of load carried by the sides
L = length of panel
b = breadth of panel

then $r=\frac{L^4}{L^4+B^4}$

Having found the proportions of load to be carried each way the bending moment is found as for a continuous slab, there being of course the proper amount of steel placed in the top over supports to care for negative bending moments.

When the length of the panel exceeds 1.5 times the breadth the portion of load carried by the cross beams is within the area found by drawing lines at an angle of 45° from each corner to an intersection.

All the foregoing calculations can be dispensed with by using expanded metal and reinforcing for load across short span. The mesh being diamond shaped the strands run in the right directions to care for all strains developed in the slabs. See pages 1 and 2, Roof and Floor Slab booklet.

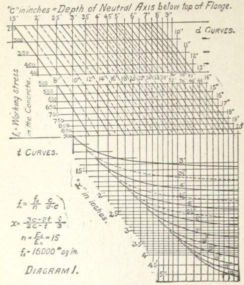
HOW TO FIGURE BEAM SIZES.

The formulas given on pages 4 and 7 are all that are necessary to determine the sizes of beams and girders. The width of a beam should be not less than 1/24 the span. The best proportioned beam is that in which $b = \frac{1}{2}h$ to $\frac{2}{3}h$. Assuming that the beam and slab it carries will be poured at one operation the top of the beam may be taken as the top of the slab. If not poured at one operation the top of the beam will be at the bottom of the slab thus increasing total depth.

Beams may often be figured as of T section and some concrete saved. Diagram 2 contains a cut of such a beam. Properly proportioned "b" should not exceed ¼ the span length of the beam, or it should not exceed $6t + b'$.

The formulas already mentioned may be used to compute such beams and the steel proportioned accordingly. The steel is a percentage of the rectangle bd. The stem b′ however needs only to be wide enough to contain the steel and its enveloping concrete. In computing shear b′ is used and not b. The slab thickness should be not less than 1/5d.

Diagrams 1 and 2 are for the design of T beams. Entering the upper half of Diagram 1 at the concrete fiber stress, intersect with the d curve and follow the c line down to the slab thickness. On the left is found x.

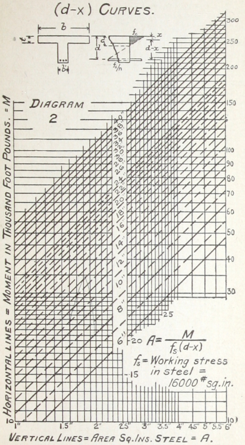


Subtract x from d. Find bending moment in foot pounds. Enter Diagram 2 on line representing this bending moment. Follow to an intersection with the d-x, just found. Drop vertically to the steel area in square inches.

The slab thickness is found in the Roof and Floor Slab booklet, preferably. The depth is generally governed by the head room wanted. That the conditions for a properly designed beam may be fulfilled $b \overline{\gtrless} \frac{M}{R\,d^2}$ and if these conditions are not fulfilled at the first trial, try again.

HOW TO FIGURE EXPANDED METAL REINFORCEMENT.

The loading being assumed and the spans determined, bending moments are calculated as shown on pages 5 and 7. The formulas on pages 4 or 7 are then used to obtain the depth of the slab and the area of reinforcement.



(Diagrams for Reinforced Concrete Design, by G. F. Dodge, is a new book containing complete diagrams for solving all problems.)

TABLE VIIa

Specification for the Reinforcement:---"Three inch mesh, Northwestern Expanded Metal, weighing 0.82 lb. per sq. ft. Laid to give an area of 0.263 sq. ins. per 12" width."

SPAN		3'6"	4'	4'6"	5'	5'6"	6'	7'	8'	9'	10'	11'	12'
Total Slab Thickness	Slab Weight per Sq. Ft.	SUPERIMPOSED SAFE LOADS IN POUNDS PER SQUARE FOOT.											
		1-2-4 Broken Stone or Washed Gravel Concrete.											
2"	24	129	93	68	51	37	28	14	5				
2½	31	220	174	130	100	77	60	35	20	9			
3"	37	370	277	212	170	124	100	88	41	25	13		
3½	43	520	385	295	210	185	150	95	65	40	25	14	
4"	49	610	455	350	270	215	165	110	75	50	30	17	7
4½	55	705	525	405	300	255	195	135	90	60	38	22	10
5"	61	810	605	465	365	290	235	155	105	70	45	27	13
		1-2½-5 Broken Stone or 1-5 Bank Gravel Concrete.											
6"	73		755	580	455	365	295	195	135	95	60	35	20
7"	85		915	695	550	440	355	240	160	110	75	47	25
8"	98			820	645	520	420	280	190	130	88	55	30
9"	110			895	740	590	480	325	220	150	100	65	37
10"	122			945	830	665	540	365	250	170	115	75	44

TABLE VIIIa

Specification for Reinforcement:--"Three inch mesh, Northwestern Expanded Metal weighing 1.36 lb. per sq. ft. Laid to give an area of 0.433 sq. ins. per 12" width."

SPAN		6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'	17'
Total Slab Thickness	Slab Weight per Sq. Ft.	SUPERIMPOSED SAFE LOADS IN POUNDS PER SQUARE FOOT.											
		1-2-4 Broken Stone or Washed Gravel Concrete.											
2"	24	32	19	7									
2½	31	78	49	30	17	8	2						
3"	37	125	78	54	35	21	11	3					
3½	43	187	126	87	60	40	26	15	6				
4"	49	255	174	122	86	60	41	27	15	7			
4½	55	333	230	165	118	85	60	42	28	17	7		
5"	61	415	289	207	151	110	81	58	40	26	15	6	
6"	73	518	362	265	181	139	103	75	53	35	21	10	
7"	85	629	439	316	232	172	127	93	67	46	29	15	
8"	98	734	513	370	274	201	150	110	79	55	35	19	6
		1-2½-5 Broken Stone or 1-5 Bank Gravel Concrete.											
9"	110	843	590	426	313	233	173	128	93	65	42	24	8
10"	122	952	667	482	355	264	198	147	106	75	49	29	11

Table XVI gives data by which to select a weight of slab to carry certain live loads. Along the top are placed the live loads. In the left hand column is the weight per square foot of the slab and in the columns under the live loads are the spans. Enter the table on the top at the assumed live load. Drop down to the assumed span, or one nearest to it. On the right will be the weight of slab to carry that load on that span. This is of course for the first trial as each slab requires a trial and final calculation. If the proportion is too great then it is best to assume 1.5 times the live load for the total load and equate for span.

At this point look in the tables of stock sizes for the area coming nearest to the one found. To obtain the full effect of expanded metal the edges of the sheets should lap at least one mesh so the whole reinforcement will act as one sheet. This lap is counted in as part of the reinforcement.

All slab calculations can be avoided by using the tables in the Roof and Floor Slab booklet and the additional tables VIIa and VIIIa in this booklet.

TABLE XVI

Approximate weight per square foot of concrete slabs for indicated live loads and spans.

Weight in lbs. Sq. Ft.	LIVE LOADS IN POUNDS PER SQUARE FOOT.												
	25	50	75	100	125	150	200	250	300	350	400	450	500
	SPANS IN FEET $M = \frac{wl^2}{8}$												
25	5	4	4	3									
35	8	7	6	5	5	5	4	4	3	3			
45	9	8	7	6	6	6	5	4	4	4	4	3	3
50	10	9	8	7	7	6	6	5	5	5	4	4	4
55	11	10	9	8	8	7	7	6	6	5	5	5	4
60	13	11	10	9	9	8	7	7	6	6	6	5	5
70	14	12	11	10	9	9	8	7	7	6	6	6	6
75	15	13	12	11	10	10	9	8	8	7	7	6	6
85	16	15	14	13	12	11	10	9	9	8	8	7	7
100	18	16	15	14	13	13	12	11	10	9	9	9	8
110	20	18	17	16	15	14	13	12	11	11	10	10	9
125	21	19	18	17	16	15	14	13	12	12	11	11	10
140	22	21	20	18	18	17	15	14	14	13	12	12	11
150	24	22	21	20	19	18	17	16	15	14	13	13	12

Table XVIII shows the reinforcing value per 12″ width of various weights of expanded metal in 3″ mesh, for different side laps. For example an area of 0.336 sq. ins. per 12″ width is wanted. The table shows that a sheet of 3″ mesh, #19 6 ft. wide lapped one mesh on the side will give the required area. If the area wanted had been 0.351 sq. ins. it would required a sheet three feet wide lapped one mesh on the side.

If expanded metal is found to lack area, even when lapped, the deficiency can be supplied by wiring bars to the sheets at intervals or by placing down the middle of each sheet a strip of expanded metal one, two, three or four meshes wide of some heavier strand. This is best, for the meshes nest very nicely so the moment arm is not increased whereas the extra thickness of the bar must be taken into account.

TABLE XVII

Areas in square inches of strips of Northwestern Expanded Meta for additional reinforcement as a substitute for bars or rods.

NUMBER	WIDTHS OF STRIPS.			
	1 MESH	2 MESHES	3 MESHES	4 MESHES
7	.016	.033	.049	.065
9	.024	.049	.073	.097
11	.015	.030	.044	.059
13	.027	.055	.082	.109
15	.041	.081	.122	.162
17	.061	.122	.183	.243
19	.081	.162	.243	.324
21	.10	.20	.30	.40

AREAS AND WEIGHTS OF EXPANDED METAL

If it is decided to use sheets 3′ wide (the most convenient), divide the length of the panel by 2.75 to obtain number of sheets lapping 3″ on edge. Add to the total length (width of panel × number of panels) 1′ for end bearings. Divide total length by 11.25 to get number of sheets 12′ long; or by 7.25 to get number of sheets 8′ long. This gives 9″ end lap.

If the tables do not contain the required area proceed as follows: Determine area by the proper formulas. Multiply this area in sq. ins. per 12″

Width of Sheets—Feet	3 INCH MESH Area per 12" width 0.059 sq. ins. Wt. per sq. ft. 0.2 lbs.			2¼ INCH MESH Area per 12" width 0.087 sq. ins. Wt. per sq. ft. 0.370 lbs.			3 INCH MESH Area per 12" width 0.109 sq. ins. Wt. per sq. ft. 0.370 lbs.			Width of Sheets—Feet
	Area Sq. Ins. 12" Wide			Area Sq. Ins. 12" Wide			Area Sq. Ins. 12" Wide			
	One Mesh Lap	Two Mesh Lap	Three Mesh Lap	One Mesh Lap	Two Mesh Lap	Three Mesh Lap	One Mesh Lap	Two Mesh Lap	Three Mesh Lap	
2	.066	.074	.081	.095	.103	.111	.123	.136	.150	2
3	.064	.069	.074	.093	.098	.103	.118	.127	.136	3
4	.063	.066	.070	.091	.096	.099	.116	.123	.129	4
5	---	---	---	---	---	---	---	---	---	5
6	.061	.064	.066	.090	.092	.094	.113	.118	.123	6
7	.061	.063	.065	.089	.092	.094	.113	.117	.121	7
8	.061	.063	.065	.089	.091	.093	.112	.116	.119	8
9	.061	.062	.064	.089	.091	.092	.112	.115	.118	9
10	---	---	---	---	---	---	---	---	---	10
12	.060	.061	.063	.088	.089	.091	.111	.113	.116	12

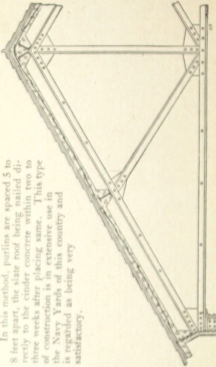
	2¼ INCH MESH Area per 12" width 0.13 sq. ins. Wt. per sq. ft. 0.44 lbs.			3 INCH MESH Area per 12" width 0.162 sq. ins. Wt. per sq. ft. 0.55 lbs.			3 INCH MESH Area per 12" width 0.243 sq. ins. Wt. per sq. ft. 0.81 lbs.			
2	.142	.154	.166	.182	.203	.223	.273	.304	.334	2
3	.138	.146	.154	.176	.189	.203	.263	.283	.304	3
4	.136	.142	.148	.172	.182	.193	.258	.273	.289	4
5	---	---	---	.170	.178	.186	.255	.267	.279	5
6	.134	.138	.142	.169	.175	.182	.253	.263	.273	6
7	.134	.137	.141	.168	.174	.178	.252	.260	.269	7
8	.133	.136	.139	.167	.172	.177	.251	.258	.266	8
9	.133	.135	.138	.166	.171	.176	.250	.256	.263	9
10	---	---	---	.166	.170	.174	.249	.255	.261	10
12	.132	.134	.136	.165	.169	.172	.248	.253	.258	12

	3 INCH MESH Area per 12" width 0.324 sq. ins. Wt. per sq. ft. 1.07 lbs.			3 INCH MESH Area per 12" width 0.4 sq. ins. Wt. per sq. ft. 1.36 lbs.			
2	.365	.405	.445	.450	.500	.650	2
3	.351	.378	.405	.433	.467	.500	3
4	.344	.364	.385	.425	.450	.475	4
5	.340	.356	.372	.420	.440	.460	5
6	.336	.351	.364	.417	.433	.450	6
7	.335	.347	.359	.414	.427	.444	7

TABLE XVIII

Showing increase in average area per 12" width by lapping sheets of Expanded Metal

wide by 36". Divide the product by 39 which will give the area per 12" wide to call for in sheets 3' wide lapping 3" on the edge. The weight per sq. ft. = area sq. ins. per 12" wide × 3.396.



In this method, purlins are spaced 5 to 8 feet apart, the slate roof being nailed directly to the cinder concrete within two to three weeks after placing same. This type of construction is in extensive use in the Navy Yards of this country and is regarded as being very satisfactory.

USE OF FACTOR TABLES.

On page 18, Roof and Floor Slab booklet, is a table of factors for use in converting quantities in the tables into equivalent quantities under other bending moment assumptions.

Given a span of 6' to carry a safe superimposed (live) load of 50 lbs. per sq. ft.

Table VII, page 11, same book, a slab $2\frac{1}{2}$ ins. thick will do. Weight of slab 31 lbs., making total load 81 lbs. per sq. ft.

Partially continuous slab. (p. 18)

$s' \times 1.12 = 6 \times 1.12 = 6.72'$ new span for same slab. $w' \times 1.25 = 81 \times 1.25 = 101$ lbs. sq. ft. new total load $101 - 31 = 70$ the new live load for same slab.

If original load is sufficient and span of 6 feet is all right, then; $\frac{W}{1.25} = \frac{81}{1.25} = 65$, new total load for 6 foot span.

The nearest to this is to be found in Table VI, page 10, where the live load is 32 lbs. and the dead load 31 lbs. while the reinforcement is cheaper. The total load is 63 lbs. and the span freely supported. $63 \times 1.25 = 79$ lbs. partially continuous. The total load is always considered and the ultimate load is four times the total load.

The same calculations can be made for continuous slabs, using 1.22 instead of 1.12 when dealing with spans; and 1.50 instead of 1.25 when dealing with loads.

For square slabs the following example will suffice. A panel 10 ft. sq. is loaded 90 lbs. to the sq. ft. In Table IX, page 13, we find for a freely supported slab the slab will be 5″ thick and the reinforcement consists of 3″ mesh, 10 ga. single strand with ⅝″ sq. bars 18″ on centers wired to the sheet. Total load=152 lbs.

In this example we must find a new slab and new reinforcement to carry the same load on a square panel.

$\frac{W}{2.50} = \frac{152}{2.50} = 61$ lbs. total load per sq. ft.

We must look then in the other tables to find a slab to carry a total load of 61 lbs. per sq. ft. on a span of 10′ with a slab less than 5″ thick.

The nearest to this is found in Table VIII, page 12, where a slab $3\frac{1}{2}$″ thick will do, reinforced with 3″ mesh, 10 ga. D. S. There will be two layers at right angles and the concrete must be increased half an inch for the extra layer, thus making the slab 4″ thick. In this example one inch of concrete is saved, thus reducing weight but no saving in cost is effected. However the slab is reinforced properly, which is the aim of good design.

In the tables the factor of safety is four. The total load is the sum of the weight of slab and superimposed safe load. Multiply total load by 4 for breaking load. Deduct weight of slab to get load that must be placed on slab to break it. One-fourth of this may be assumed as the live load and we will then be designing as some men design.

EXAMPLE. — Roof and Floor Slab booklet, page 11, Table VII, span 10′, load 17 lbs. per sq. ft., weight of slab 73 lbs., total load 90 lbs. Breaking load (total) $90 \times 4 = 360$ superimposed breaking load. $360 - 90 = 270$ lbs. One-fourth of 270 lbs. = 67.5 lbs., a load greater than usually figured for dwellings and porch floors.

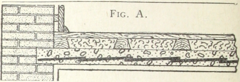
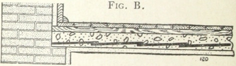


FIG. A.

The three cross-sections, Figures A, B and C, illustrate different methods of supporting reinforced concrete floors on brick walls, and different methods of finishing the floors. In Figures A and B the plastering is applied directly to the underside of floor slabs. In Figure B an underfloor is first nailed to the concrete and to this underfloor the finished floor is nailed.

FIG. B.


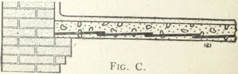


FIG. C.

STRESSES USED IN CALCULATING THE TABLES.

The tables have been calculated by the formulas given in this booklet, allowing a thickness of concrete of three quarters of an inch below the center of the steel (half an inch covering) when the expanded metal alone is used; and one inch when bars are used in combination with the expanded metal.

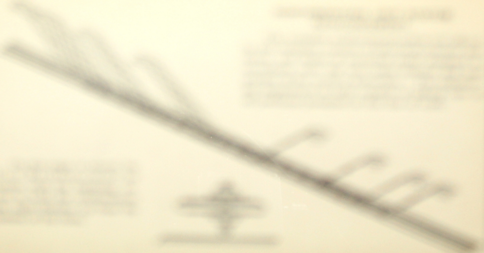
The fiber stress in the concrete was assumed at 700 lbs. and this governed the strength of the slab in the thin slabs at the tops of the tables. The steel stress of course is low in those slabs. As the slabs became thicker however the steel stress increased until it reached 16,000 lbs. per sq. in. after which that value was maintained and the concrete stress grew less, this being met by changing the character of the concrete. The same method was used in the slabs reinforced with the bars and mesh combined but in this case the steel stress was allowed to go to 18,000 pounds per sq. in. as a maximum.

WEB REINFORCEMENT.

In such a booklet as this the subject of internal stresses in beams and proportioning of web reinforcement can hardly be gone into thoroughly. The reader is referred to standard treatises on reinforced concrete. When the span exceeds ten times the depth of the beam it is seldom that web reinforcement is needed. When the beam however is comparatively deep as compared with the length the question of web reinforcement assumes importance.

Web reinforcement is supplied by stirrups, upright or inclined. Inclined stirrups are most efficient and it is important that they go far enough up to permit of secure anchorage in the concrete in compression in the top of the beam or slab. Many beams fail by diagonal tension in spite of the imbedded stirrups because the stirrups are too short. Many beams fail with stirrup reinforcement because the stirrups are not rigidly attached to the horizontal reinforcement.

THE NORTHWESTERN UNIT BEAM (pat. apl. for) is a beam fabricated in our factory and shipped flat to destination, the stirrups being bent up into position by the workmen. The construc-



tion is simple and readily understood. There are as many strips of expanded metal as there are stirrups on one half the beam. These strips form part of the horizontal reinforcement and are bent up at each end to act as stirrups and are bent horizontally at the top for anchorage. The method of clamping all the sheets together and attaching them to the rods or bars is also patented and this fastening is adjustable so the reinforcement can be held at any desired height above the bottom of the form. The patent covers the use of wire fabric as well as expanded metal. The expanded metal nests perfectly so that no trouble is experienced in pouring the concrete.

COLUMNS.

The accompanying column diagram is so simple as to require little explanation. The horizontal lines represent the total load in thousands of pounds carried by the column. The diagonal line at the right shows where the steel alone will carry the load. The vertical lines indicate area of steel in square inches. The full curves give sizes of columns of reinforced concrete when the concrete stress is 500 lbs. per sq. in. and the dotted curves give sizes of columns when the concrete stress is 350 lbs. per sq. in. The steel stress is 15 times the concrete stress. The reinforcement is supposed to consist of bars or rods (smooth, not deformed) placed vertically in the forms at least two inches away from the face of the column, and tied together at intervals equal to the side of the column, by No. 8 wire. The dimensions of the columns here given are the dimensions necessary for strength and the two inches all round required for fire protection must be added to these dimensions.

Some concrete is necessary to protect the steel and it cannot be relied on for compressive strength for a fire will injure it. However the size of the column may be kept down by designing it for a 350 lb. compressive stress and setting the steel in 1½" from the faces. A fire will then injure only the outside skin which will result in the concrete thereafter carrying a higher stress within the steel while the outer concrete may be plastered over to hide the effects of the fire.

[illegible]

This diagram can be used for hooped columns by first ascertaining the amount of vertical steel required. The same amount of steel in the form of expanded metal wrapped as hooping can be figured on as carrying a stress 2½ times that allowed in the vertical steel. The Northwestern Expanded Metal Co. fabricates in the factory column reinforcement composed of vertical rods wired to sheets of light expanded metal, which ties them together instead of the wire mentioned. These columns are shipped out flat and set in place by the workmen, the mesh being bent on the job. This company will also send the columns out already bent into box shape if desired but of course the freight will be higher. Hooped, or wound columns, in which the hooping is heavy expanded metal are also fabricated to order at the factory and shipped out ready to set up.

COST OF WORK.

In response to many inquiries as to cost of work we offer the following tables taken from a paper read by Mr. Leonard C. Wason, President of the Aberthaw Construction Company, Boston, Mass., at the Fifth Annual Convention of the National Association of Cement Users, January 1909. The reader should obtain a copy of the full paper in order to analyse these costs properly. In looking at the item of steel it is well to know that expanded metal is the lowest in cost of erection of any form of reinforcement steel. The steel costs

STEEL.

Location.	Weight, Tons.	Cost of Handling.	Cost per Ton.
Office building, Portland, Me.	324½	$5,115.32	$15.76
Fire station, Weston, Mass	8½	40.26	4.74
Mill, Chelsea, Mass	65¼	548.81	8.41
Coal bins, Dalton, Mass	8½	61.75	7.26
Dam, Auburn, Me	55	506.76	9.18
Filter, Warren, R. I.	19	102.59	5.40
Tank, Lincoln, Me	8½	69.38	8.16
Tar well, Springfield	15½	59.21	3.82
Monument, Provincetown	24½	136.84	5.58
Mill, Greenfield	92¾	1,232.01	10.20
Machine shop, Milton, Mass	20¼	177.16	8.75
Coal pocket, Lawrence, Mass	28	461.16	16.47
Mill, Southbridge	53½	142.76	2.67
Mill, S. Windham, Me	293	3,079.60	10.51
Mill, Attleboro, Mass	49½	286.02	5.78
Garage, Newton, Mass	20	86.55	4.33
Mill Southbridge, Mass	30	100.03	3.34
Coal pocket, Hartford, Conn	195	2,316.60	11.88
Filter, Lawrence, Mass	44½	112.84	2.54
Warehouse, Portland, Me	62	462.99	7.47
Standpipe, Attleboro, Mass	199⅓	1,547.00	7.75
Highest	...	....	16.47
Lowest	...	....	2.54
Average of 21	...	....	8.52

given here apply only to cost of putting in place and do not cover the purchase prices. On an average the cost of a number of office buildings from other authorities, has been taken as follows, the costs being expressed in percentages; Labor 40%; cement 14%; stone and sand 10%; steel 20%; lumber 11%; miscellaneous 5%.

The reader must remember that the costs were obtained by a very large corporation engaged exclusively in reinforced concrete work and employing as superintendents and foremen experienced, skilled men. The average contractor handling occasional jobs cannot hope to reach these figures except under very favorable circumstances.

COST OF BUILDING WALLS ABOVE GRADE.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire. $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Fire station, Weston, Mass.	.115	.033	.004	.158	.100	.007	.069	.053	.026	.039	.294
Mill, Greenfield, Mass.	.062	.038	.002	.102	.060	.011	.084	.086	.007	.055	.303
Waterworks, Waltham, Mass.	.137	.024	.001	.162	.146	.007	.058	.057	.014	.047	.329
Coal pocket, Lawrence, Mass.	.118	.056	.002	.176	.042	.004	.073	.043	.009	.019	.190
Mill, Attleboro, Mass.	.103	.024	.001	.128	.129	.018	.074	.048	.017	.043	.329
Coal pocket, Hartford, Conn.	.096	.047	.002	.145	.118	.052	.097	.055	.017	.013	.350
Filter, Lawrence, Mass.	.046	.032	.001	.079	.046	.017	.083	.054	.012	.032	.244
Italian garden, Weston, Mass.	.101	.073	.002	.176	.102	.008	.105	.081	.019	.010	.325
Stable, Beverly, Mass.	.099	.030	.002	.131	.078	.019	.071	.062	.018	.010	.258
Residence, N. Andover, Mass.	.078	.016	.001	.095	.096	.014	.046	.050	.008	.019	.174
Observatory, Milton, Mass.	.056	.038	.002	.096	.095	.012	.060	.187	.058	.005	.417
Office, Boston, Mass.	.105	.030	.002	.137	.096	.033	.066	.114	.066	.005	.350
Tunnel, Boston, Mass.	.112	.045	.005	.162	.126	.016	.066	.106	.077	.005	.320
Hospital, Waltham, Mass.	.058	.028	.001	.087	.089	.017	.024	.063	.023	.010	.236
Residence, Boston, Mass.	.108	.036	.001	.145	.110	.015	.077	.069	.026	.005	.446
Coal pocket, Providence, R. I.	.087	.020	.001	.108	.052	.005	.102	.090	.015	.010	.274
Italian garden, Brookline, Mass.	.064	.027	.001	.092	.048	.011	.050	.071	.019	.010	.229
Highest	.139	.073	.005	.176	.146	.052	.105	.187	.077	.055	.446
Lowest	.046	.016	.001	.079	.042	.004	.024	.043	.007	.005	.174
Average of 17	.085	.026	.002	.128	.090	.016	.073	.076	.025	.019	.301

COST OF FOOTING AND MASS FOUNDATIONS.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire. $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Power house, Greenfield	.119	.077	.002	.198	.065	.020	.098	.092	.008	.016	.299
Eng. foundation, Taunton, Mass.	.054	.025	.001	.080	.045	.002	.065	.048	.004	.017	.181
Head gates, Shawmut, Me.	.071	.043	.003	.117	.033	.001	.074	.099	.003	.014	.224
Canal, Lowell, Mass.	.039	.025	.001	.065	.025	.011	.080	.078	.004	.042	.240
Foundation, Provincetown	.069	.043	.002	.114	.039	.004	.073	.099	.011	.049	.275
Dam, Merrimack, N. H.	.066	.037	.003	.106	.081	.008	.090	.055	.008	.031	.273
Foundation, Boston, Mass.	011	.006	.001	.018	.035	.004	.061	.072	.006	.010	.188
Eng. foundation, Boston, Mass.	.095	.039	.003	.137	.037	.013	.061	.084	.013	.015	.223
Gas holder, Springfield	.034	.031	.002	.067	.043	.001	.061	.068	.005	.010	.188
Foundation, Providence, R. I.	.016	.011	.001	.028	.051	.002	.047	.076	.010	.010	.198
Highest	.119	.077	.003	.198	.081	.020	.098	.099	.013	.049	.275
Lowest	.016	.006	.001	.018	.025	.001	.047	.043	.003	.010	.181
Average of 10	.057	.034	.002	.093	.045	.007	.071	.077	.007	.021	.229

COST OF FOUNDATION WALLS.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire. $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Filter, Warren, R. I.	.103	.048	.004	.155	.062	.037	.086	.068	.012	.031	.296
Tar well, Springfield	.071	.031	.002	.104	.040	.015	.094	.075	.013	.040	.277
Tunnel, New Bedford	.048	.045	.001	.094	.213	.019	.203	.092	.057	.015	.599
Filter, Exeter, N. H.	.124	.067	.002	.193	.064	.021	.071	.116	.034	.019	.325
Filter, Lawrence, Mass.	.058	.042	.001	.101	.046	.017	.083	.054	.012	.032	.244
Theatre, Portland, Me.	.081	.024	.003	.108	.112	.013	.073	.078	.003	.020	.303
Warehouse, Portland, Me.	.053	.009	.001	.063	.040	.019	.060	.070	.029	.017	.235
Residence, N. Andover	.047	.019	.001	.067	.108	.006	.082	.045	.015	.010	.266
Filter, Lawrence, Mass.	.048	.035	.002	.085	.055	.006	.039	.027	.011	.010	.148
Residence, No. Andover	.065	.019	.001	.085	.087	.012	.072	.045	.013	.010	.239
Retaining wall, Naugatuck, Conn.	.134	.047	.001	.182	.097	.018	.056	.032	.022	.010	.235
Hospital, Waltham, Mass.	.048	.028	.001	.077	.043	.019	.038	.063	.026	.010	.199
Greenhouse, Brookline, Mass.	.032	.035	.001	.068	.051	.007	.078	.043	.013	.010	.202
Hotel, Brookline, Mass.	.037	.018	.001	.056	.043	.002	.080	.054	.010	.010	.199
Highest	.134	.048	.004	.193	.213	.037	.203	.116	.057	.040	.599
Lowest	.032	.009	.001	.056	.040	.002	.038	.027	.003	.010	.148
Average	.068	.033	.002	.103	.076	.015	.080	.062	.019	.017	.269

COST OF BEAM FLOORS OF REINFORCED CONCRETE.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire. $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Power house, Greenfield	.165	.107	.003	.275	.143	.020	.109	.101	.008	.016	.397
Tar well, Springfield	.064	.041	.002	.107	.076	.005	.026	.075	.013	.040	.335
Mills, Greenfield, Mass.	.106	.061	.004	.171	.077	.011	.109	.086	.007	.055	.345
Car barn, Danbury, Conn.	.044	.051	.001	.096	.128	.013	.086	.071	.011	.010	.319
Coal pocket, Lawrence, Mass.	.072	.039	.002	.113	.056	.004	.073	.041	.009	.019	.202
Mill, Southbridge, Mass.	.067	.062	.002	.131	.137	.029	.191	.051	.038	.014	.460
Mill, Attleboro, Mass.	.062	.032	.002	.096	.071	.023	.098	.062	.021	.055	.330
Bridge, Plymouth, Mass.	.047	.050	.001	.098	.078	.019	.100	.040	.027	.010	.247
Garage, Newton, Mass.	.104	.033	.002	.134	.116	.020	.121	.084	.038	.010	.394
Mill, Southbridge, Mass.	.057	.051	.001	.109	.119	.027	.132	.037	.013	.034	.362
Coal pocket, Hartford, Conn.	.060	.033	.001	.094	.047	.023	.081	.055	.017	.013	.236
Garage, Brookline, Mass.	.105	.038	.002	.145	.160	.032	.088	.058	.041	.020	.399
Filter, Lawrence, Mass.	.048	.032	.001	.081	.102	.016	.085	.054	.012	.032	.301
Storehouse, Chelsea, Mass.	.064	.043	.002	.109	.153	.035	.115	.068	.052	.020	.443
Warehouse, Portland, Me.	.037	.029	.001	.067	.186	.030	.096	.069	.043	.046	.470
Textile mill, Lawrence, Mass.	.045	.042	.001	.088	.130	.013	.071	.037	.025	.010	.286
Textile mill, Lawrence, Mass.	.053	.033	.001	.087	.116	.033	.194	.049	.035	.015	.442
Chapel, Portland, Me.	.053	.027	.002	.082	.100	.008	.127	.091	.041	.010	.377
Highest	.165	.107	.004	.275	.186	.035	.194	.101	.052	.055	.470
Lowest	.037	.027	.001	.067	.047	.004	.071	.037	.007	.010	.202
Average of 18	.070	.045	.002	.116	.111	.020	.106	.063	.025	.024	.354

COST OF FLAT SLAB FLOORS.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire. $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Office building, Portland, Me.	.078	.039	.001	.118	.043	.004	.087	.084	.012	.032	.252
Fire station, Weston, Mass.	.067	.038	.003	.108	.103	.007	.092	.053	.026	.039	.320
Church, Boston, Mass.	.067	.037	.002	.106	.146	.017	.109	.072	.020	.010	.374
Highest	.078	.039	.003	.118	.146	.017	.109	.084	.026	.039	.374
Lowest	.067	.037	.001	.106	.043	.004	.087	.053	.012	.010	.252
Average	.071	.038	.002	.111	.097	.009	.096	.070	.019	.024	.315

COST OF CONCRETE COLUMNS.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Office building, Portland, Me.	.133	.039	.001	.173	.064	.004	.087	.084	.012	.022	.273
Coal pocket, Lawrence, Mass.	.057	.024	.001	.082	.166	.003	.073	.041	.008	.016	.307
Mill, Southbridge, Mass.	.097	.082	.002	.181	.073	.056	.107	.035	.027	.030	.328
Mill, Attleboro, Mass.	.093	.022	.001	.116	.110	.014	.062	.038	.013	.034	.271
Mill, Southbridge, Mass.	.080	.056	.001	.137	.108	.048	.100	.037	.013	.034	.340
Coal pocket, Hartford, Conn.	.098	.047	.002	.147	.089	.043	.069	.055	.017	.013	.286
Garage, Brookline, Mass.	.071	.051	.002	.124	.070	.028	.072	.058	.041	.020	.289
Warehouse, Portland, Me.	.118	.016	.001	.135	.087	.027	.087	.070	.039	.025	.335
Textile mill, Lawrence, Mass.	.061	.013	.001	.075	.095	.019	.109	.027	.018	.015	.283
Highest	.133	0.82	.002	.181	.166	.056	.109	.084	.041	.034	.340
Lowest	.057	.013	.001	.075	.064	.003	.062	.027	.008	.013	.271
Average of 9	.082	.036	.001	.130	.096	.027	.085	.049	.021	.023	.301

COST OF CONCRETE SLABS BETWEEN STEEL BEAMS.

Location.	Forms per square foot. Carpenter labor. $	Lumber. $	Nails and wire. $	Total. $	Concrete per cubic foot. Concrete labor. $	Gen. labor. $	Cement. $	Aggregate. $	Team and misc. $	Plant. $	Total. $
Bleachery, E. Hampton	.054	.027	.002	.083	.092	.007	.137	.073	.012	.046	.367
Machine shop, Milton, Mass.	.087	.027	.003	.117	.090	.033	.114	.075	.016	.034	.362
Foundry, N. Britain, Conn.	.078	.046	.002	.126	.095	.021	.076	.078	.004	.022	.296
Stable, Boston, Mass.	.064	.012	.001	.077	.101	.019	.129	.070	.020	.015	.354
Residence, Milton, Mass.	.110	.071	.003	.184	.105	.048	.132	.080	.053	.010	.428
Power House, Pittsfield, Mass.	.029	.030	.001	.060	.131	.008	.123	.068	.013	.010	.353
Laundry, Boston, Mass.	.058	.024	.001	.083	.092	.021	.098	.089	.022	.010	.332
Prison, Portsmouth, N. H.	.068	.017	.001	.086	.073	.005	.208	.075	.006	.010	.377
Paper mill, Mittineague	.097	.071	.002	.170	.144	.033	.143	.062	.027	.010	.419
Power house, Quincy, Mass.	.047	.025	.001	.073	.073	.021	.159	.085	.064	.020	.422
School, Waltham, Mass.	.029	.028	.001	.058	.138	.009	.102	.078	.018	.015	.360
Foundry, Providence, R. I.	.028	.020	.001	.049	.084	.012	.114	.026	.026	.010	.272
Foundry, Providence, R. I.	.043	.021	.001	.065	.111	.010	.128	.029	.029	.010	.317
Highest	.110	.071	.003	.184	.144	.048	.208	.080	.064	.046	.428
Lowest	.028	.012	.001	.049	.073	.005	.076	.026	.004	.010	.272
[illegible]	.061	.032	.002	.095	.102	.019	.128	.068	.024	.017	.359

STOCK SIZES FABRIC

NORTHWESTERN EXPANDED METAL CO.

CHICAGO, ILLINOIS

In reinforced concrete design factors of safety are based on elastic limit of steel and not on ultimate strength. NORTHWESTERN EXPANDED METAL has an elastic limit exceeding 60,000 lbs. per sq. in. (Tests made March, 1909, by Messrs. Robert W. Hunt & Co.)

NO.	Area in sq. ins. per 12" width	Weight in lbs. per Sq. Ft.	Elastic Limit per 12" width in pounds	Length of Sheets.	Approximate Dimensions. Inches				NO.
					b	l	t	w	
1	.203	.69	12200	8'	½"	1½"	1/20	5/64	1
3	.253	.86	15200	8'	¾"	2"	7/64	5/64	3
5	.188	.64	11300	8' & 12'	1½"	3"	7/64	7/64	5
7	.087	.29	5220	8'	2¼"	6"	1/16	1/8	7
9	.130	.44	7800	8'	2¼"	6"	1/16	3/16	9
11	.059	.20	3540	8' & 12'	3"	8"	1/16	7/64	11
13	.109	.37	6550	8' & 12'	3"	8"	7/64	1/8	13
15	.162	.55	9700	8' & 12'	3"	8"	9/64	9/64	15
17	.243	.81	14600	8' & 12'	3"	8"	9/64	7/32	17
19	.324	1.07	19400	8' & 12'	3"	8"	9/64	9/32	19
21	.40	1.36	24000	8' & 12'	3"	8"	3/16	13/64	21
23	.245	.84	14700	8' & 12'	6"	12"	15/64	1/4	23
25	.368	1.26	22100	8' & 12'	6"	12"	15/64	3/8	25

No's 1, 3 and 5 are used for screens and nettings. Also for plastering lath. These sizes are often used for reinforcing shingles, tubs, burial vaults, etc., in which mortar (not concrete) is used. Small mesh not good in concrete.

No's 7 and 9 are used in light slabs but a 3" mesh is better; same weights and areas.

No's 11, 13, 15, 17, 19 and 21 are best for reinforcement. No's 23 and 25 are not quite as flexible as the same weights in the 3" mesh

No. 6. SIDEWALKS.—Contains details of sidewalk construction in accordance with Building Ordinance requirements in many cities, together with tables of quantities of material so that the labor of the designer is reduced to a minimum. Ready May 15th, 1909.

No. 7. SEWERS AND CULVERTS.—Contains detail drawings for circular, egg-shaped and square sewers and culverts with tables of quantities and valuable formulas and data. Ready June 1st, 1909.

No. 8. TANKS AND WALLS.—Contains valuable formulas and data for the design of walls with tables of quantities for the reinforcement of walls illustrated in the booklet. A valuable book for designers and for dealers. Ready June 15th, 1909.

No. 9. SLAB BRIDGES.—This should really be termed Girder Bridges, for the Sewer and Culvert booklet deals with slab bridges up to spans of ten feet. This book gives detail drawings and tables of quantities of flat girder and slab bridges.

No. 10. ARCH BRIDGES.—Similar in scope to Slab Bridges but dealing entirely with arches.

Booklets 9 and 10 should be in the hands of every engineer, road supervisor, county surveyor and contractor. Ready July 15th, 1909.

In addition to the foregoing booklets it is the intention of the NORTHWESTERN EXPANDED METAL COMPANY to issue at fairly regular intervals reprints of articles on subjects of special interest to concrete workers and to issue also works of an original nature describing methods for use of expanded metal and metal plastering lath.